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Design and Construction of 1KW (1000VA) Power Inverter

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Abstract

The purpose of this project is to design and construct a 1000Watts (1KW) 220 Volts Inverter at a frequency of 50Hz. This device is constructed with locally sourced components and materials of regulated standards. The basic principle of its operation is a simple conversion of 12V DC from a battery using integrated circuits and semiconductors at a frequency of 50Hz, to a 220V AC across the windings of a transformer. An additional power supply to the public power supply with the same power output is thus provided at an affordable price.

Keywords: Inverter, integrated circuits, semiconductors, transformer, power supply.

1. Introduction

In this modern society, electricity has great control over the most daily activities for instance in domestic and industrial utilization of electric power for operations. Electricity can be generated from public supply to consumers in different ways including the use of water, wind or steam energy to drive the turbine as well as more recently the use of gas. Generators, solar energy and nuclear energy are also source of electricity [1].

In Nigeria, there is inconsistence supply of electricity by the power supplying company to the consumers. Hence the use of additional electric power source such as electric power generators and most recently the use of semiconductor power devices such as the Bipolar Transistor, Thyristors and particularly MOSFET to generate electric power in conjunction with a DC battery in few kilowatts. An Inverter offers a better additional power source to Generators as well as UPS considering its long duration, cost effectiveness and maintainability.

1.1 The Electronic Power Generator and the Uninterrupted Power Supply (UPS)

The electronic power generator can be simply describe as an engine which burns fuel to generate electricity at a desire frequency in alternating current (AC) form [4]. The limitation of using generator as alternative or additional source of electricity includes:

Noisy: Most of the power generators are noisy during its operation, which causes disturbances to the neighbourhood.

Environmental threat: The smoke and the black oil from the generator pose threats to the environment as air and soil or water pollutant.

Bulky: Most generators are big and planted. Therefore, generation of power at remote places is not too easy.

Expensive: Cost of maintenance is high compare to an Inverter. This make it quite unaffordable by people with low income.

UPS on the other hand only serves as a back up and do not retain or provide power for a longer duration.

1.2 Inverter

An inverter is used to provide uninterrupted 220V AC supply to the load connected to its output socket. It provides constant AC supply at its output socket, even when the AC mains supply is not available [4].

It is a combination of inverter circuit, charger circuit and a battery. The charger circuit keeps the battery charged when the mains supply is available and when the mains AC fails, the inverter circuit takes the DC power stored in the battery and converts it into 220V/50Hz AC supply, which can be used to power any common electronic equipment or computer systems. It performs the reverse role of rectifier where the AC power is converted into DC power and functions by chopping DC voltage through various means.

Most of the electrical equipment work with the 220V AC supply but internally, their circuit work on the DC supply. Hence the external AC supply is converted into DC supply by the power supply unit on these equipments. Any device that works on DC supply can be used during the mains power breakdown by connecting them to batteries. But batteries have a fixed life and running power consuming equipment using the battery could be very expensive [9]. Hence, rechargeable batteries can be used in this type of situation to reduce the cost. An inverter is used to power device that does not have the facility to connect to a DC power source or device that requires AC power source for its operation.

The use of semiconductor power devices such as bipolar transistors, thyristors for voltage amplification, particularly the MOSFET as the power switches, makes the inverter a better additional power supply. The inverter is less noisy, provides complete automatic switchover function, posses no environmental threats, less bulky and less expensive to maintain.

1.3 Components used in the design

For this project to be complete, there is a need to know the components used in the design. In electronics, the power system is designed in such a way that the equipment always has power so that it can function effectively. These components include:

- Integrated Circuit(IC) SG 3524 PWM
- IC NE 555 Timer
- IC LM 393 (LM 324) Comparator
- Transistor
- Metal Oxide Semiconductor Field Effect Transistor (MOSFET)
- Transformer
- Relay Switch
- Rectifier
- Capacitor
- Diode, Light-Emitting Diode (LED)
- Resistor
- Breakers
- Opto Isolator
- Operational Amplifier

2. Calculation analysis

This section deals with the actual calculation used to obtain parameter for the design. All components used in the construction were sourced locally and adequate adjustments were made on all available substitute components in order to achieve the best result of the device under construction.

2.1 Determination of the Oscillating Frequency

By supplying a constant 12Volt DC through a voltage regulator to the IC SG 3524 PWM, the frequency of the oscillating signal was determined using a 10KΩ variable resistor connected in series with another 56KΩ resistor and both connected in parallel with 0.22µF to form the RC time constant network.

Frequency, f = $\frac{1}{1.1 * C_T R_F}$ where

Time Capacitor (C_T) = 0.22µF

Fixed Resistor (R_F) = 56KΩ

Variable Resistor (V_R) = 10KΩ

Time Resistor (R_T)=56KΩ+10KΩ = 66KΩ

Therefore, f = $\frac{1}{1.1 * 0.22 * 10^{-6} * 66 * 10^{3}}$

f = 62.6Hz

It should be noted that the variable resistor was varied until the frequency of the signal was 50Hz.

2.2 Determination of the Transistor (MOSFET) Switching Current

The MOSFET used is the IRF 150 in the power switching circuit due to high switching speed. By using 3.67volts supplied by the two NPN and the two PNP transistors, the switching time (T) is determined from the oscillating frequency as well as the gate switching current $I_{G.}$

T = $\frac{1}{f}$ = $\frac{1}{50Hz}$

T = 0.02sec

I_G = $\frac{Cdv}{dt}$ = $\frac{1000 * 10^{-6} * 3.67}{0.02}$

I_G = 183.5ηA

2.3 The Drain Current of the MOSFET

From the Inverter, total power is 1000Watts,

The battery Voltage is = 12V

Therefore, the drain current I_D = $\frac{P}{V}$

I = $\frac{1000}{12}$

I_D = 83.3A

Where the voltage output of the inverter, V_{output} = 220V

Full load output current, $I_{output} = \frac{P}{V}$

$$= \frac{1000}{220}$$

$$I_{output} = 4.5A$$

2.4 The Transistor used in the Buffer Circuit

Two NPN C1815 transistors were used as signal buffer circuit connected in the common emitter mode having the following characteristics:

Characteristics	Value
Collector to Base Volts BV_{CBO}	70
Collector to Emitter Volts BV_{CEO}	70
Base to Emitter Volts BV_{EBO}	4
Max Collector Current I_C Amps	0.4
Max Device Diss P_D Watts	0.6 ($T_A = 25^0C$)
Frequency in Mhz	120min
Current hfe	120min

Table 2.1

2.5 Analysis of Power Switch Circuit

Inverter power output (P) = 1000Watts

Output voltage, V = 220V

Inverter Input = battery output voltage =12V

Frequency = 50Hz

Power factor = 0.8

Apparent power (s) = $\frac{\mathrm{Re}\,alPower(P)}{PF}$

$$= \frac{1000}{0.8}$$

$$= 1250VA$$

Therefore, the full load current flowing at the transformer primary;

Real power (P) = current (I) * voltage

$$1000 = I * 12$$

Hence, $I = \frac{1000}{12} = 83.3A$

3. Design, construction and testing

3.1 Design of the Inverter Circuit

This circuit uses IC SG3524 PWM which functions as oscillator together with TC 4066 BP which functions as switch to generate the oscillating signal that controls the switching ON and OFF of the gate of a 6-numbered MOSFETS connected in parallel to a center-tapped transformer. This switches the 12V DC from the battery, across the windings of the transformer to produce a 220V AC at 50Hz frequency for the use of computers and other domestic appliances with maximum power rating of 1000watts.

LM 393 IC (a comparator) and NE555 (a timer) incorporated in the circuit function to detect overloading and low battery in the inverter.

Generally, inverter is a combination of a battery, a charger circuit and an inverting circuit as shown in the figure 3.1 below.

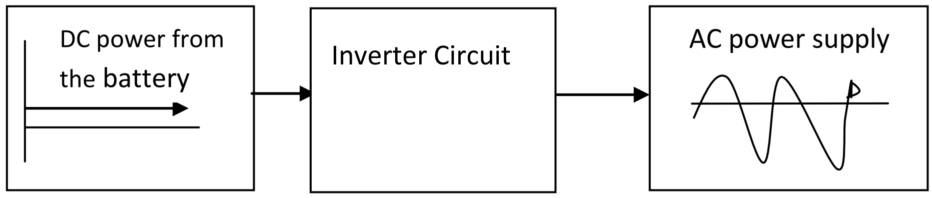

Fig 3.1 Schematic diagram of an Inverter

3.1.1 The Battery

The battery is a two-terminal device that provides DC supply to the inverter section when the AC mains is not available. This DC is then converted into 220V AC supply and output at the inverter output socket.

It is pertinent to state that lead-acid batteries used in automobiles are very good for this purpose as they provide good quality power for a long duration and can be recharged once the power stored in them are consumed. The backup time provided by the inverter depends on the battery type and its current capacity.

3.1.2 The Inverter Circuit

This circuit charges and discharges the battery when there is AC mains supply and when the AC mains is not available respectively. The basic block and circuit diagram of this project is as shown in figure 3.2 and 3.3 below.

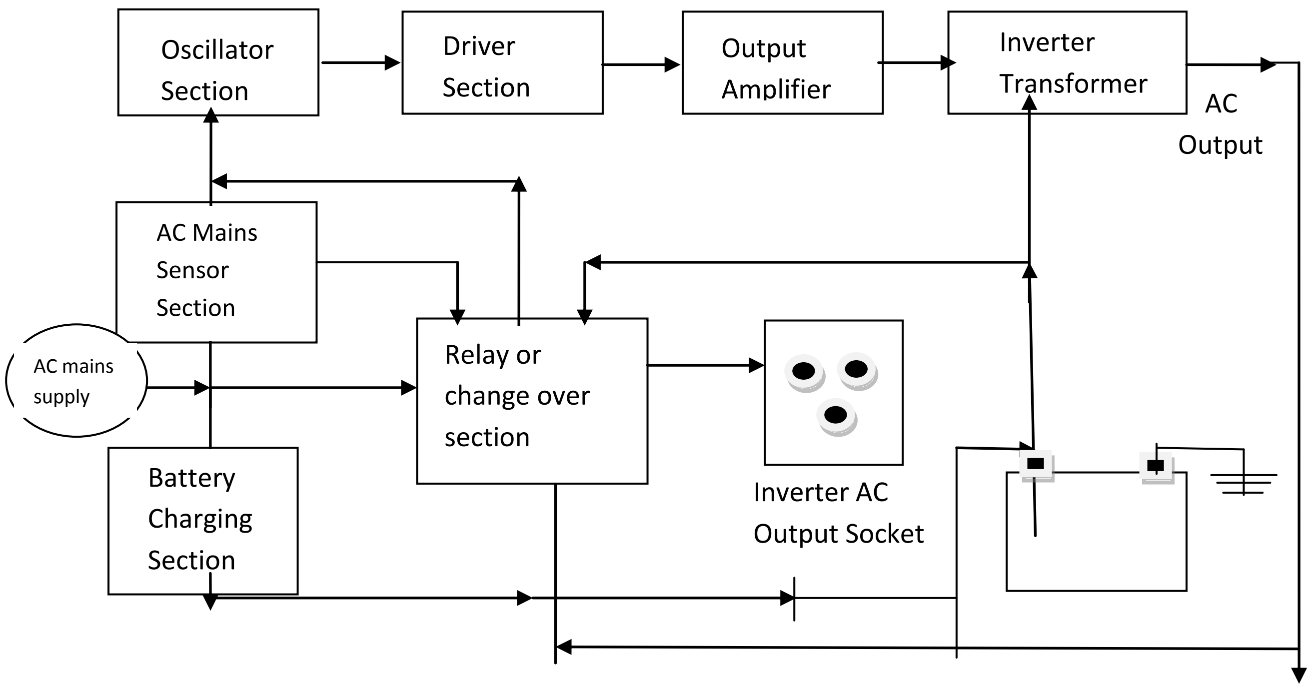

Fig 3.2 Basic Block Diagram of an Inverter

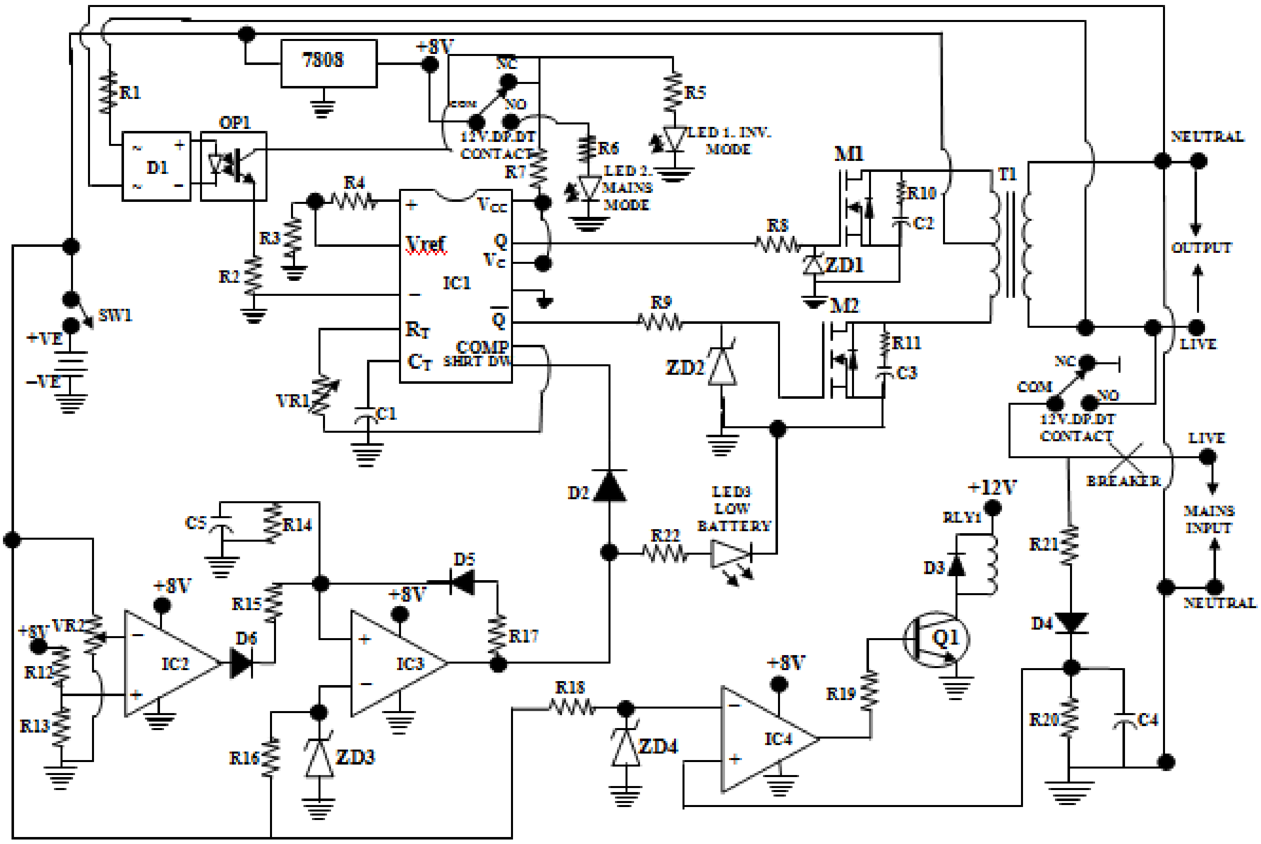

Fig 3.3 The complete diagram of an Inverter system

3.1.3 The AC Mains Supply

The AC input supplies a 220V AC, 50Hz from the public supply. This is connected to the charger circuit where it is rectified to DC voltage and through the relay switch to the output of the inverter to bypass the inverter when there is public electric power supply while the battery is charging.

3.1.4 The AC Mains Sensor

This inverter uses a 0 - 18V/1Amp triggering transformer and a regulator to sense the AC mains supply. When the AC mains supply is available, this supply is given to the primary winding of the triggering transformer to give 18V AC supply at the secondary winding. It is then rectified by bridge rectifier and input to filter capacitors which convert the 18V supply to 12V DC supply. The 12V supply stays constant even when there is a change in the AC mains supply and the inverter is informed about the availability of the AC mains supply whenever there is.

3.1.5 The Oscillator

This section uses a pulse width modulator PMW IC SG 3524 to generate the 50Hz frequency required to generate AC supply by the inverter. The relationship between the frequency, resistance and capacitance has been given before as :-

$$\text{Frequency, } f = \frac{1}{1.1 * C_T R_F}$$

The battery supply is connected to the IC SG 3524 through the inverter ON/OFF switch. The flip-flop converts the incoming signal into signals with changing polarity such that in a two-signal with changing polarity, the first is positive while the second is negative and vice versa. This process is repeated 50times per second to give an alternating signal with 50Hz frequency at the output of SG3524. This alternating signal is known as "MOS Drive Signal ".

3.1.6 The Driver and the Output Amplifier

The MOS drive signals are given to the base of MOS driver transistor which results in the MOS drive signal getting separated into two different channels. The transistors amplify the 50Hz MOS drive signal at their base to a sufficient level and output them from the emitter.

The 50Hz signal from the emitter of each of the transistor is connected to the gate G of all the MOSFETS in each of the MOSFET channel, through the appropriate resistance [7].

3.1.7 The Inverter Transformer

The transformer used for this project has a center-tapping which divides the primary into two equal sections. This center-tapping is connected to the positive terminal of the battery. Two ends of the primary are connected to the negative terminal of the battery through switches S1 and S2. These switches S1 and S2 are turned ON/OFF alternatively to generate current in the primary coil. When the switch S1 is closed and S2 is opened, the current flows in the first part of the primary winding and the EMF is induced in the secondary winding. When the switch S2 is closed and S1 is opened, the current flows in the second part of the primary winding and the EMF of opposite polarity is induced in the secondary winding. Thus, if the switches S1 and S2 are alternatively opened and closed at constant rate, then the output from the secondary winding is a square wave of the frequency at which the switches S1 and S2 are opened and closed. In the circuit of figure 4.5 the transformer is said to be connected in "push-pull-mode" [10].

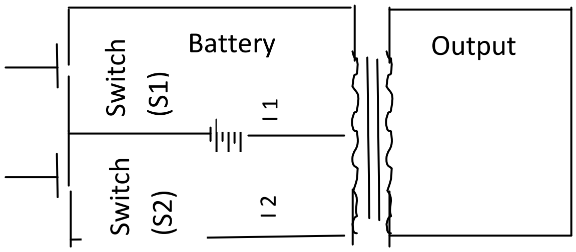

Fig 3.4 Basic circuit of an inverter transformer

3.1.8 The battery Charger

When the inverter section receives AC mains supply, it stops operation but the charger section in the inverter starts its operation. In this mode, the inverter transformer works as a step down transformer and output 12V at its secondary winding. During the charging, MOSFET transistors at the output section works as rectifier with the drain working as the cathode while the source works as the anode. The center-tapping of the transformer receives positive supply and the MOSFET source 'S' receives negative supply from the battery. The center-tapping is connected to the positive terminal of the battery and the MOSFET source S is connected to the negative terminal with a shunt resistance. Thus, when the inverter receives AC mains supply, inverter transformer and MOSFET together work as a charger and charge the battery.

3.1.9 The Change Over

This section is used to switch ON the inverter when the AC mains supply is OFF and to switch OFF the inverter when the AC mains supply returns (ON). During changeover, when the inverter receives AC mains supply, it stops drawing the battery supply and the AC mains supply at the inverter input is directly sent to the inverter output socket. This is done using a one, two-pole relay.

3.1.10 Inverter AC Output

The AC output gives a 220V AC, 50Hz either directly from the input when the AC mains supply is available or from the inverter circuit action on the battery when the AC mains supply is not available. Computers and other household appliances are connected to this output.

3.1.11 Protections

The AC input to this device was fused with a 5Amp fuse to protect the transformer as well as the rectifying circuit in case of over voltage, and high current which could flow into the transformer.

3.1.12 Indicators

Three indicators are connected to the front of the inverter; a red colour shows that the inverter is charging as well as delivering a 220V AC from its output terminal. Green colour indicates that the inverter is discharging from the battery and yellow indicates that it is delaying.

3.1.13 Switch

A switch is connected to the front of the inverter. This red switch controls the AC voltage input and output of the inverter.

3.2 Construction

The step by step approach taking in the construction of this project started with the building of the transformer from the laminating core, followed by the rectification stage, sensing and monitoring stage, comparator and transistor switching. The tools and instruments used include:

- Lead and Soldering Iron
- Lead sucker
- Copper stripping knife
- Cutter
- Razor blade
- Plier
- Digital Multimeter
- Fero and bread board

To conform to the requirement of this project, temporary construction of the prototype was done on bread board before finally transferring it onto the fero-board for permanent soldering. The circuit was constructed, tested and put to use under proper load conditions. In other to achieve accuracy in the design, some necessary adjustments were made to some of the components used.

3.3 Casing

The complete unit was housed in a metallic red casing. Battery terminals for positive and negative, power switch, handle and output meter were fixed in their allotted slots and connected to their respective points on the circuit. The casing was earthed and each stages carefully arranged inside and connected together.

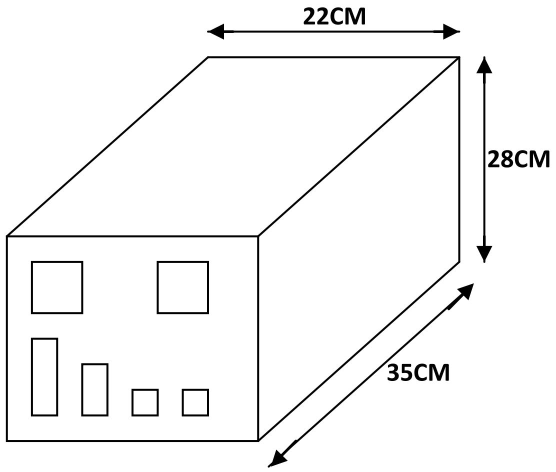

Fig 3.5 Inverter Casing

Fig 3.6 Front view of an Inverter

Fig 3.7 Side view of an Inverter

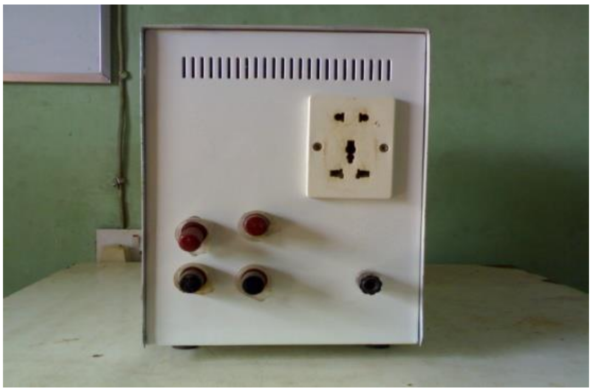

Fig 3.8 Back view of an Inverter

3.4 Testing

While constructing, all components used were tested to ascertain their conformity with the required standard of the objective of this project. The output voltage of the inverter was a square wave, filtered by a 2 μF/400V capacitor connected across the output terminals to remove the unwanted harmonics and leaving smooth sine waveform output voltage.

3.4.1 Testing of the Inverter under load condition

The duration at which the inverter discharges under load condition depends on the total power of load connected to its output terminal and the power rating of the battery connected to its input terminal. Bearing in mind that total load must not exceed 1000watts.

Discharge duration

(a) Battery power rating = 12volts, 60Ampere per hour

When total load = 150watts

Then duration = $\dfrac{12*60}{150}$

= 4.8hours

(b) Battery power rating = 12volts, 60Ampere per hour

When load = 300watts

Then duration = $\dfrac{12*60}{300}$

= 2.4hours

4. Conclusion and Recommendations

4.1 Conclusion

The construction of this 1000Watts (1KVA), 220Volts inverter at a 50Hz frequency was a gradual process from gathering of materials to testing of components. It is to be noted that the efficiency of this project depends on the power rating of the battery connected to the input and on the total power of the load connected to its output terminals. Thus, the inverter could deliver constant power for a calculated number of hours.

In view of the inconsistence and unreliable public power supply and high cost of electric power generators coupled with the high cost of maintenance, the inverter is found to offer a better constant additional power supply for a sustainable duration. It is noiseless, harmless, and cost effective. It is also a preferred power backup to a computer and other appliances because it switches automatically to the battery when the AC mains is not available. Thus reduce system breakdown, prevent hard disk damages and data loss. In addition, the life span of the computers and other devices connected to either a standby or a continuous inverter is prolonged.

4.2 Recommendations

Although the objectives of this project has been achieved, the inverter cannot be used to power any device of higher power rating. In addition, when the inverter is operating on mains supply, any fluctuation of the AC input gets to the inverter output.

Therefore, for improvement on this project, further research can include:

- increasing the power rating of the inverter by increasing the number of the power switching devices and the current rating of the transformer.

- Converting the inverter to acts like a UPS (Uninterrupted Power Supply) through an additional Automatic Voltage Regulator (AVR).

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